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A full-Stokes polarimeter for the GREGOR Fabry-Perot interferometer

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Abstract. One of the first post-focus instruments of the new solar telescope GREGOR will be a Fabry-Perot spectrometer, which is an upgrade of the Göttingen Fabry-Perot interferometer at the Vacuum Tower Telescope (VTT) on Tenerife. This spectrometer is equipped with a full-Stokes polarimeter. The modulation is performed with two ferroelectric liquid crystals, one acting nominally as quarter-wave plate, and the other as half-wave plate. A modified Savart plate serves as polarimetric beam splitter. With the present liquid crystals, the optimum wavelength range of this polarimeter is between 580 and 660 nm. The spectro-polarimeter will benefit from the capabilities of the new telescope GREGOR which will provide a spatial resolution of about $0\farcs1$ (75 km on the solar surface). Thus we will be able to investigate small magnetic features, and we will study their development with high cadence.

Keywords. Instrumentation: polarimeters – instrumentation: spectrographs – Sun: magnetic fields

1. Introduction

The new 1.5 m solar telescope GREGOR (see Volkmer, von der Lühe, Kneer, *et al.*, 2007), which will become operational in the near future, will be able to resolve solar features with a size of 75 km. At this time, an upgrade of the Göttingen Fabry-Perot Interferometer (GFPI) described by Puschmann, Kneer, Seelemann & Wittmann (2006) will be moved to GREGOR. Spectrometers based on Fabry-Perot interferometers scan through spectral line profiles, thus allowing to record a two-dimensional image at each wavelength position. They have a high transmission enabling faster cadences compared to grating spectrographs, which allow us to study rapid processes on the Sun. Small solar magnetic features such as filigrees, G-band bright points, penumbral filaments and umbral dots undergo changes within a few minutes. To understand the physical processes behind these changes, it is important to observe the development of the features with short time intervals. The GFPI originally described by Bendlin, Volkmer & Kneer (1992) is presently installed at the Vacuum Tower Telescope (VTT) on Tenerife where a long experience with FPIs exists. Recently, the GFPI has been equipped with a full-Stokes polarimeter, and first results have been presented by Bello González & Kneer (2008).

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2. The Polarimeter

The modulation of the polarimeter is performed with two ferroelectric liquid crystal retarders (FLCR). FLCRs can be switched between two fixed orientations of their fast axis. Nominally, the first FLCR in the beam has a retardation of $\lambda/2$ and the second one has a retardation of $\lambda/4$. FLCRs can be switched with kHz-rates, which is an advantage over nematic liquid crystals. High modulation rates are required in applications with post-facto image reconstructions, *e.g.* speckle reconstruction. The presently used pair of FLCRs can be used in the spectral range from 580 to 660 nm with reasonable efficiency. We intend to purchase another pair of FLCRs for a different wavelength range.

Behind the FLCRs, positive and negative polarization components are separated by a modified Savart plate which consists of two calcites rotated by 180° with a half-wave plate inbetween, as suggested by Keller (2006). The half-wave plate exchanges ordinary and extraordinary beams, so that they have both the same amount and orientation of astigmatism caused by the calcites. Thus, we achieve a wide separation and the same optical length for both beams. For each of the four modulation states of the FLCRs an exposure is taken. We obtain a linear combination of the four Stokes parameters which must be demodulated by software.

The position of the polarimeter is just in front of the CCD detector in the converging beam where the requirements on optical quality are relaxed. Instrumental polarization must be corrected. For this purpose, a calibration unit, which is described by Hofmann, Rendtel & Arlt (2008), is mounted near GREGOR's secondary focus. The optical beam before this point is axisymmetric and introduces almost no instrumental polarization.

The spectral resolution power of GFPI is 250,000 at 600 nm. A photospheric line profile is typically covered within about 40 scanning steps, and eight exposures per step and Stokes parameter enable image reconstruction (see below). The CCD detector has a sensitive area of 1376×1040 pixels. The typical readout speed is 15 images per second, and the single exposure time is 10 ms. Thus, scanning the line profile and recording the full Stokes vector takes about 85 s. Recording only circular polarization is possible. The field-of-view of the polarimeter will be about $25'' \times 39''$. Binning and readout of a selected part of the image can be used to increase the frame rate.

Simultaneously to the narrow-band spectral data, images in a broad-band channel are taken. These images allow a speckle reconstruction, and the deconvolution function obtained this way can be applied to the polarized images (see Keller & von der Lühe, 1992). An application to VTT observations was presented by Bello González & Kneer (2008). A userfriendly software package for all basic data reductions is under development.

In combination with the high spatial resolution of the 1.5 m GREGOR telescope, the new GREGOR spectro-polarimeter will be a powerful instrument to study the dynamics of small-scale magnetic features on the Sun.

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